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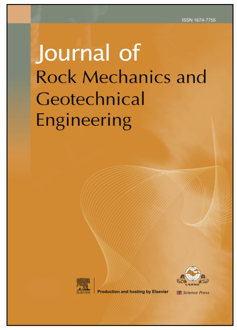


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PII: S1674-7755(17)30351-7

DOI: 10.1016/j.jrmge.2017.12.006

Reference: JRMGE 432

To appear in: *Journal of Rock Mechanics and Geotechnical Engineering*

Received Date: 18 September 2017

Revised Date: 6 December 2017

Accepted Date: 10 December 2017

Please cite this article as: Aziznejad S, Esmaieli K, Hadjigeorgiou J, Labrie D, Response of jointed rock masses subjected to impact loading, *Journal of Rock Mechanics and Geotechnical Engineering* (2018), doi: 10.1016/j.jrmge.2017.12.006.

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ACCEPTED MANUSCRIPT

Journal of Rock Mechanics and Geotechnical Engineering

Journal online: www.rockgeotech.org

# Responses of jointed rock masses subjected to impact loading

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Received 18 September 2017; received in revised form 6 December 2017; accepted 9 December 2017

**Abstract:** Impact-induced damage to jointed rock masses has important consequences in various mining and civil engineering applications. This paper reports a numerical investigation to address the responses of jointed rock masses subjected to impact loading. It also focuses on the static and dynamic properties of an intact rock derived from a series of laboratory tests on meta-sandstone samples from a quarry in Nova Scotia, Canada. A distinct element code (PFC2D) was used to generate a bonded particle model (BPM) to simulate both the static and dynamic properties of the intact rock. The calibrated BPM was then used to construct large-scale jointed rock mass samples by incorporating discrete joint networks of multiple joint intensities into the intact rock matrix represented by the BPM. Finally, the impact-induced damage inflicted by a rigid projectile particle on the jointed rock mass samples was determined through the use of the numerical model. The simulation results show that joints play an important role in the impact-induced rock mass damage where higher joint intensity results in more damage to the rock mass. This is mainly attributed to variations of stress wave propagation in jointed rock masses as compared to intact rock devoid of joints.

**Keywords:** jointed rock mass; impact loading; microcracks; rock damage

## 1. Introduction

In many civil and mining engineering applications, rock materials are subjected to dynamic loading. They often have to withstand not only static loads but also impact loads due to explosions or collisions with other objects (e.g. drill bits, other rock boulders). Drill-and-blast method is commonly used for rock fragmentation in mining and civil engineering. During percussive drilling, the drilling bit continuously hits the rock materials in order to break the rock and make a hole. In blasting, a rock mass is subjected to a dynamic shock generated by explosives. Another example of impact loading can be found in ore pass systems, in underground mines, that are commonly used to transfer ore or waste from one mining level to a lower level using gravity. Collision of broken materials, flowing in an ore pass, with the ore pass walls can cause impact-induced damage and result in wear along the ore pass (Goodwill et al., 1999; Esmaieli and Hadjigeorgiou, 2011, 2014). In all of these examples, the rock fracture mechanism and fragmentation process occur under impact loading conditions. Hence, the behavior of rock under impact loading is of interest and importance.

Modeling the responses of rock materials under dynamic impact load is difficult given the transient nature of loading. According to Hiermaier (2013), under impact loading conditions, two basic processes occur: a change in the mechanical behavior of the material as a function of the strain rate, and the evolution and propagation of shock waves. Although many studies on rock material response under static conditions can be found in the literature, fewer studies have been reported on the behaviors of rocks under dynamic loading due to their higher complexity. In addition, the presence of pre-existing discontinuities in rocks such as joints, bedding planes, and foliations can significantly influence the responses of rock materials under both static and dynamic loads.

There are several laboratory experimental methods to quantify the responses of rock materials to impact loading (Camacho and Ortiz, 1996; Xia and Ahrens, 2001; Momber, 2003; Grange et al., 2008; Gao et al., 2010; Cao et al., 2011; Hiermaier, 2013). There are theoretical models for the evolution of rock damage under impact loading (Taylor et al., 1986; Ahrens and Rubin, 1993; Cao et al., 2011). Although dynamic impact laboratory testing of small intact rock samples is straightforward, impact testing of large rock mass samples is costly and inherently complex. An issue in these analytical models is that quite often there are too many parameters involved and thus it is difficult to quantify them. Furthermore, only a few of the results of the analytical investigations can be confidently extrapolated to practical applications.

In the past, both continuum and discontinuum numerical modeling tools have been used to determine the behaviors of rocks under dynamic impact loading (Beus et al., 1999; Nazeri et al., 2002; Hu and Li, 2006; Grange et al., 2008; Wang and Tonon, 2010; Cao et al., 2011). Continuum-based numerical models are used to simulate rock damage by idealizing the material as a continuum and utilizing the degradation measurements in constitutive relations. Gao et al. (2010) simulated the dynamic impact loading of an intact rock using LS-DYNA, a finite element code, and analyzed the dynamic responses of the rock under

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